

## **Explaining Economic Growth and Total Factor Productivity in Thailand**

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### **Abstract**

The purpose of this research is to investigate the economic growth and Total Factor Productivity (TFP) in Thailand by introducing the Generalized Autoregressive Conditional Heteroskedastic (GARCH) technique. The notion of productivity used in this study is the Solow's residual, estimated through the Cobb-Douglas production function in the Thai economy during 1979-2005. Unfortunately, the log likelihood function tends to reject the AR(1)-GARCH(1,1) specification in favor of the AR(1) process. Nonetheless, significant coefficients of conditional variance is very close to unity, implying that any shock to variance has substantial persistence, and the Thai economy cannot be explained by rational expectations. The factors' accumulation statistically indicates more significant importance than the improvement of quality of factors and economic instability. Foreign direct investment (FDI) possesses a negative and significant effect in all models while the proxy of input quality is powerless in explaining growth. Therefore, the implication of development policy in promoting FDI would not be sustained economic growth and, in turn, could harm the welfare grounds. However, the import of capital goods as a proxy of the indirect technological diffusion leads to positive technological knowledge spillovers from developed nations. Technological change is obviously inseparable from human interaction, and therefore inseparable from human capital. Lastly, policymakers seem to gain credibility in achieving economic stabilization.

**Keywords:** TFP, Economic Growth, GARCH, Knowledge Spillovers

## 1. Introduction

Over the years, interest in approaching the high growth rate of economy has been growing, especially in developing countries, including Thailand. However, the achievement of accelerated growth rate might be unsustainable in the long term as the result of special characteristics and uncontrollable factors such as globalization and new innovation. Thus, high growth rate of the economy is not the only target, but it must also be sustainable. This has currently become a more challenging strategies to policymakers. The productivity and efficiency of the economy are widely used as indicators by which to maintain economic growth because productivity and efficiency are indicative of the structural changes and innovations in production processes.

Ideally, the development of economic growth models and the progress toward a more complete understanding on the determinants of long-run economic success will provide more insightful information to policymakers in answering questions concerning economic growth. Thus, the interest in productivity studies has been raised and conducted partially due to academic and non-academic interests, and regulatory purposes. Several theoretical models and econometric techniques are applied to explain the growth rate of gross domestic product (GDP). Many studies have recently attempted to explain the phenomenon of input productivity, including total factor productivity (TFP) or miscellaneous material productivity, which provides the dominant source of output growth, by various methods through production or cost functions. Base on the original work of the fixed-factor proportions model of Harrod (1939), Domar (1946), and the dual-sector model of Lewis (1954), Solow (1956) introduced a simplified economic growth model that was different from later theories. The model generally specified a neoclassical production function, where physical capital, labor, and exogenous technology influence output levels.

If TFP indicates improvement, the production processes of that country (or industry) will then experience improved economic efficiency. Higher economic efficiency technically implies the achievement of sustained growth Tinakorn and Sussangkarn (1994) among others, for example, have bolstered a helpful study to explain the growth of economy by using the Solow-Dimension analyticity of

production underlying the production function. They apply a growth accounting framework which may be easier by which to calculate total productivity growth from year to year. However, this estimated technique does not take serial correlation effect into account in capturing technological progress. Thus, it is important that growth theories and empirical models are needed to be reapplied from the later works.

The investigation on the growth rate in the Thai economy is unfortunately limited in terms of regression technique and time horizons. Hence, this paper specifically tends to augment Solow's model by applying the empirical growth accounting framework. The powerful econometric technique, so-called ARCH model, with the Cobb-Douglas's production function is introduced in order to explain the growth of the Thai economy and the technological progress to TFP in the past three decades. For proper estimating specification, the outcomes from these powerful techniques will be needed in order to make a comparison to traditional techniques, the ordinary least square. In addition to be more facilitate the understanding of economic processions, additional variables are utilized in order to capture the effect of technological transferring, knowledge accumulation, human capital, and macroeconomic uncertainty on rates of growth. This completed understanding will eventually provide insightful information for policy makers in promoting the sustainable growth.

The organization of this paper will be as follows: section 2 broadly contains the relevant literature, while the next section briefly describes data characteristics. The aspect of empirical methodologies is summarized in section 4 followed by the empirical findings which are reported in two main parts: section 5 presents the summary statistics, and section 6 explains the empirical results. Finally, in the last section of the paper, the concluding remarks are provided.

## **2. Review of Relevant Literature**

The revival of interest in growth theory with the development of new growth models and regression had opened new avenues of research and initiated several debates. The major research approach is to answer the process of growth and to find the vital components of output growth. Although many implications of these models are not new, they are different and innovative in several aspects.

Solow (1956) developed a production function, applying the concept of a remarkable characteristic of the Harrod-Domar model of which consistently studies long-run problems with the usual short-run tools under the standard of neoclassical conditions. Solow's production function is constructed under the model of long-run growth which accepts all the Harrod-Domar assumptions except for those of fixed

proportions. Technically, the model softens the rigid assumptions and takes the qualitative effect as neutral technological change and interest-elastic saving schedule into account. Certainly, works in the area of economic growth continued after Solow's (1956) development of the neoclassical model, and these works, follow as refinements of his model.

One may observe a new path of analyzing and determining economic growth in form of the new neoclassical endogenous growth models which depart from neoclassical theory. Romer (1986) and Lucas (1988) initially introduced an endogenous growth theory that focused on explaining Solow's residual, instead of factor accumulation and productivity (TFP) growth. This alternative theory generally considers the effects of numerous variables such as human capital, trade, technological change and the different mechanisms of technological diffusion, and capacity of technological absorption. In this respect, technology is considered as an endogenous variable that could be transferred from one (developed country) to another (developing country) through the trade of goods. The findings indicate that technological innovation and a quality of factors are important explanations of TFP growth, as well as absorbed foreign technology. The main source of TFP growth in developed countries was in technological innovation. Meanwhile, the developing countries still faced the challenge of making the best use of these imported technologies and the capacity of technological absorption.

As an alternative to the neoclassical model, Barro and Sala i Martin (1992) proposed that technology levels may be different among states or countries. The knowledge about technology would also diffuse slowly from one whose technology is more advanced to lower regions. This technological assumption is underlying the variation in technology that causes a variation in both capital and output per worker. Because of the flow of knowledge from the technology, if there is free mobility of capital across regions, income per capita will grow faster in the follower(s). This would mean that international trade or multinational corporations may facilitate the diffusion of knowledge. Feenstra (1996), among others, applied endogenous growth models with the assumption that the international diffusion of knowledge, in trading in goods can lead to a convergence of growth rates across countries.

On the other hand, the absence of knowledge diffusion can lead to a divergence of growth in the international trade of goods. Besides, Keller (1996), and López-Acevedo (2002) suggests that there is a relationship between technology and skill demand. His empirical results suggested that the demand for highly skilled workers increase after the adoption of technology. This finding also indicates the importance of complementary investment in workers training in order to realize the

productivity potential of technology. This would mean the adoption of technology that could lead to economic growth if workers had technological absorbing capacity. The training and the increases in human capital magnified technology-driven productivity gains. Maudos, Pastor and Serrano (1999) also suggested that human capital was important in order to measure the TFP growth in OECD, whereas human capital stock calculated as the number of schooling years completed by the occupied population. It highlighted the importance of efficiency as a source of variation in TFP other than technological progress. This would imply the importance of labors' absorptive capability in supporting economic growth.

Because of rising arguments about open trade regimes and rapid expansion in foreign direct investment (FDI) throughout the world economy, the growth effects of trade liberalization in the domestic realm have captured the attention of numerous economists. After opening up to international trade and capital flow, countries could access to global knowledge spillover via a number of channels. FDI is one of the most important and cheapest channels of direct technology transfer to developing countries. Li, Lui and Parker (2001), and Damijan, Knell, Majcen and Rojec (2003), for instance, examined the impact of FDI on the productivity of economy. Li, Lui and Parker detected empirically productivity spillover from the presence of FDI and from competition between local and foreign-owned firms in the Chinese manufacturing sector. As a result, a further introduction of FDI could continuously improve local technological levels which are incorporated into development strategy. In the mean time, Damijan, Knell, Majcen and Rojec failed to find evidence on positive spillover effects of FDI for domestic firms. This failure of economic contribution accorded to Borensztein et al. (1998), provided the remarkable evidence of insufficient absorptive capability of human capital in host countries by the negative effect of FDI on economic growth. They also found a strong positive interaction between FDI and level of educational attainment, and a proxy of human capital, but not in the case of domestic investment. This was possibly a reflection of differences of the technological nature between FDI and domestic investment. Therefore, the implication of development policy in promoting FDI would not perpetually be sustainable on the welfare grounds.

Moreover, Addison (2003) applied growth in a common (Cobb-Douglas) production function in order to estimate the TFP of 29 countries (13 rich and 16 poor), which assumed the similar production function to all sample countries. This study also attempted to test whether TFP, production growth less of labor and capital growth, was a function of growth in product variety and research and development (R&D) employment. As the product variety as a proxy of export, a real exchange rate was a reasonable factor by which to examine product variety. This study also found

a significant explanatory power of other miscellaneous materials, for example, the growth of capital imports (trade effect), the real exchange rate (exchange effect or macro economic stability), and price volatility (macro economic stability) to TFP growth.

In addition to the objective, it is also possible that some portion of the inflation rate will be anticipated by economic agents and capital markets. Higher degrees of this unpredictability also reflect the high levels of inflation volatility, which means increased uncertainty of inflation. This inflation uncertainty is, in turn, increased uncertainty about the future of risky investment and wealth, which may result in an increase in risk premiums. This may be because the unpredictability of future inflation is a major component of investment profitability and welfare loss associated with inflation. Moreover, as suggested by Shen (1998), because inflation risk premiums reflect perceived inflation uncertainty, changes in the size of the risk premium can reveal to monetary policy makers how credible their policy actions are in the marketplace. The introduction of inflation targeting did not immediately reduce inflation uncertain in the economy. Thus, this investigation will reveal the size of the cost of this uncertainty and the credibility of policymakers in the marketplace as a proxy of macroeconomic stability. If this is true, then output and TFP will be negatively related to inflation uncertainty. The uncertainty of inflation series data used is the residual term that is obtained from the forecast of inflation through the appropriate econometric models jointly using conventionally specified models for economic variables.

Tinakorn and Sussangkarn (1994) constructed a helpful productivity study that attempted to explain phenomenon of productivity growth by using the Solow-Demission analytical framework underlying the supply side or the production function with available data in Thailand. Generally, the residual figures were justified as the unexplained portion of output growth or TFP, commonly called technological progress under the assumption of appropriate indices to account for the increase in both quantities and qualities of all input factors. This unknown proportion is simply Solow's residual. In order to obtain TFP, they applied two approaches, a growth accounting framework and an ordinary least squared, engaged three input factors: capital, labor and land on growth of the Thai GDP in order to estimate the predictive power of relevant variables. However, there is still a major augment within both stated methodologies, regardless of their contribution on this research area in terms of calculated and estimated technique. These traditional methodologies may cause spurious estimators and, of course, implementation, productivities and value of the TFP, due to the ignorance of a serial correlation effect in both GDP growth and TFP regression, and the technical weakness of the two-step approach.

More interesting, the Office of the National Economic and Social Development Board (NESDB) of Thailand had conducted the Capital Stock of Thailand that mainly reports capital stock structure, analysis of capital factors, and the measurement of capital and total factor productivity by economic sectors and the overall economy. In order to estimate the TFP, they applied a traditional empirical growth accounting of a common Cobb-Douglas production function with three main inputs (net capital stock, labor and land) in the least square regression estimate whose residuals were treated as figures of TFP. This specific methodology of TFP estimation had also been used by the Economic Indicators Team at the Bank of Thailand (BOT), 2001. The results highlight strong evidence of TFP contribution in production (GDP). However, capital productivity had the most contributing share. Even though this study accurately extended from Tinakorn and Sussangkarn (1994), the econometric specification is still an inconclusive issue in the research area of economic growth and regression which have thus been questioned.

The numerous studies on factors productivity, over the recent years have applied various approaches. However, they have introduced similar important assumptions which allow only conditional means, but restricts the second moments or conditional variance as a constant term. One might apply the two-step approach in order to explain the TFP. However, this restriction might lead to the inefficient measurement of TFP or other material productivity. Thus, the main objective of this study is to introduce the development of an advanced econometric techniques (Autoregressive Conditional Heteroskedastic models or ARCH-type models), which can successfully capture time-varying variance or allow the TFP to change through time. The advantage of this approach is that of relaxing requirement of a two-step estimation procedure by estimation of regression innovation, TFP, and decomposing contribution to residual/variance, simultaneously.

The traditional ARCH method was originally proposed by Engle (1982), which allows a conventional regression specification for the mean function with a variance permitted to change stochastically over a particular sample period. It has been generalized by Bollerslev (1986), that Generalized Autoregressive Conditional Heteroskedastic models (GARCH models), introduces the lagged value of conditional variances into its own function. Further, allowing the conditional mean to be a formulation of the conditional variance has been extended to the GARCH model. The extensive GARCH model is known as GARCH in mean (GARCH-M), developed by Engle, Lilien and Robin (1987). If the lagged conditional variance has no predictive power on conditional variance, the extensive GARCH model is then called ARCH-M specification. Again, it must be noted that the objective of this study is not only to explain economic growth and capture the TFP, but also to introduce the ARCH-type methods as an effective technique by which to measure TFP in Thailand's economy.



Consequently, the main purpose of this survey is to approach the same question of linkage of three main inputs (capital stock, land and labor), quality of inputs (ratio of industrial labor and agricultural labor, and domestic R&D funds), macroeconomic stability (price volatility) and productivity spillover (foreign direct investment and import of capital goods) to the growth rate of output and unexplained portion or TFP, especially in the case of the Thai economy. These three main inputs and additional variables are then entered into the conditional expected growth rate of output of the underlying univariate GARCH-type models. Meanwhile, they are also employed into a conditional variance which is the square term of TFP.

### 3. Methodologies

#### 3.1 Production Function

In order to examine the economic growth and its TFP in Thailand's economy, the econometric estimation of production function is used in this study. Due to its simplicity, the most widely used form of production function has been Cobb-Douglas.  $A_t$  has commonly taken the form of an exponential time trend ( $A_t = \phi e^{\phi_t T}$ ), meaning that technological change is viewed as a shift of the production function with a smooth rate over time as mentioned by Felipe (1997). Thus, the coefficient of the trend  $\phi_T$  measures as the average of TFP growth.

In order to simplify the model, the production function form is assumed in a Cobb-Douglas form. It is not only easy to work with algebraically, but also provides a relatively accurate description of the economy. The general form at time  $t$  is given as

$$GDP_t = \{A_t, K_t^{\beta_K}, L_t^{\beta_L}, N_t^{\beta_N}\}$$

where GDP is the annual gross domestic product,  $K$ ,  $L$ , and  $N$  are physical capital, and the number of labors and usage of land inputs in Thailand, respectively. As the consequence of imperfect competition in market structure due to government intervention via macroeconomic policies, the production function does not necessarily perform a constant return to scale. Thus, the production function could be homogenous of any degree in input factors. In other words, the summation of input productivity or elasticity is not necessary equal to unity.

In order to account for factors that determine the output associated with econometric assumption, the above non-linear production function must be expressed as a linear form. The most common technique is to formulate this non-linear form as a log-linear function. The standard form of production function after changing into log



linear form is thus characterized as:

$$\ln GDP_t = \phi + \phi_T T + \beta_K \ln K_t + \beta_L \ln L_t + \beta_N \ln N_t + \varepsilon_t \quad (1)$$

where  $\ln GDP_t$ ,  $\ln K_t$ ,  $\ln L_t$ , and  $\ln N_t$  denote the logarithms of the annual gross domestic product, capital stock, labor and land, respectively.  $T$  value stands for time trend,  $T = 1, 2, 3, \dots$ . The  $\phi$ ,  $\phi_T$ ,  $\beta_K$ ,  $\beta_L$  and  $\beta_N$  are parameters to be estimated. The  $\phi_T$  measures the average growth rate of output holding other inputs constant, and  $\varepsilon_t$  is the residual term. As the technological transformation in most developing countries requires technology, a good understanding of its implementation and absorptive capacity, for instance, the average of TFP growth with technological progress can miss the fact of technological efficiency. The advanced approach of this study is not only to answer the sources of growth, but also to decompose the change in TFP into its relevant components: which are, ratio of industrial labor and agricultural labor, domestic R&D funds, inflation uncertainty, import of capital goods, and foreign direct investment, by applying an ARCH-type model. Again, the notion of productivity used is Solow's residual or  $\varepsilon_t$ , which estimates through the econometric estimation of production function. It is simply taken as the TFP of the production function.

### 3.2 Econometric Model (ARMA and ARCH-type Models)

#### 3.2.1 Production Function

Before estimating the impact of the conditional variance of annual output  $h_t$ , the mean equation for the data series must first be specified in either way. If a output series exhibits significant serial autocorrelation, an ARMA(m,n) specification is adopted as a mean equation for that series. The equation (1) can be rewritten as following:

$$\ln GDP_t = \phi + \sum_{i=1}^m \alpha_i GDP_{t-i} + \phi_T T + \beta_K \ln K_t + \beta_L \ln L_t + \beta_N \ln N_t + \sum_{i=1}^n \delta_i \varepsilon_{t-i} + \varepsilon_t \quad (2)$$

The  $\alpha$  and  $\delta$  are the interested parameters to be estimated where errors,  $\varepsilon$ , are not autocorrelated with a zero mean. If an output series does not appear to be serially correlated with the errors (or these interested parameters are statistically not different from zero), the nïve no change mean equation is employed. In other words, the mean equation turns out to be a simple production function as shown in equation (1). Although the ARMA specification can capture the problem of serial correlation of

original residuals of production function, they are not necessarily a homoskedastic process (inconstant variance  $h_t$ ).

The testing for possible existence of no conditional heteroskedasticity is constructed by regressing the squared residuals on past lags:

$$\varepsilon_t^2 = \gamma_0 + \sum_{i=1}^k \gamma_i \varepsilon_{t-i}^2 \quad (3)$$

and the procedure to derive test statistics for  $\gamma$  parameters under the null hypothesis of no conditional heteroskedasticity is:

$$H_0 = \gamma_1 = \gamma_2 = \dots = \gamma_k = 0$$

The test statistics for such a hypothesis are the both F-test and Lagrange multiplier test statistic ( $nR^2$ ) with an asymptotic  $\chi^2$  distribution. If the coefficients of the lagged squared residuals in equation (3) are all statistically significantly different from zero, the ARCH error process is then assumed. In order to capture the effects of changing volatility in a time series, the ARCH family is employed to estimate the annual output for the Thai economy.

A brief review of the ARCH family of statistical models starts with the ARCH specification, which was developed by Engle (1982). The conditional variance  $h_t$  is specified as a linear function of lagged  $q$  squared residuals,  $\varepsilon$ 's, which is, an ARCH( $q$ ) procedure, characterized as

$$h_t = a_0 + \sum_{i=1}^q a_i \varepsilon_{t-i}^2 \quad \text{where } a_i \geq 0 \quad (4)$$

The conditional variance at time  $t$  here is a positive function of the square of last  $q$  period's residuals. For  $q$  equal to zero, the variance of annual output is simply a white noise process with a mean zero and constant variance.

Bollerslev (1986) introduced the generalized ARCH model. This generalized model allows the conditional variance to be a function not only of the lagged  $q$  squared residual terms but also of its own lagged  $p$  conditional variance. That is, the GARCH( $p, q$ ) specification defines the conditional variance of annual output to be the form:

$$h_t = a_0 + \sum_{i=1}^q a_i \varepsilon_{t-i}^2 + \sum_{i=1}^p b_i h_{t-i} \quad \text{where } a_i, b_i \geq 0 \quad (5)$$

and  $a$  and  $b$  are parameters to be estimated. For  $p=0$ , equation (5) becomes the ARCH(q) process, and for  $p=q=0$  the variance of annual output is nothing but a white noise process with zero mean and constant variance<sup>1</sup>.

Furthermore, the relevant variables are added in both the conditional mean and conditional variance equation in order to test the hypothesis of both potential predictabilities of these variables for growth of the Thai economy and to decompose its TFP, respectively. To decompose the TFP by this specific econometric technique, the estimated residuals obtained from the mean equation, must behave as a heteroscedastic process. These five additional explanatory variables include: (a) RL, ratio of industrial labor and agricultural labor, (b) R&D, domestic R&D funds, (c) UINF, inflation uncertainty, (d) IMC, the import of capital goods, and (e) FDI, foreign direct investment. The descriptive validity of the estimated model can be evaluated with a likelihood ratio (LR) statistic, which is chi-squared,  $\chi^2$ , distributed. It also must be noted that the conditional variance  $h_t$  is obtained from the ARCH-type model by maximum likelihood. Nonlinear optimization techniques are used here in order to calculate the maximum-likelihood ( $L$ ) estimates based on the Berndt-Hall-Hausman (BHHH) method.

### 3.2.2 Inflation Rate

In order to estimate inflation uncertainty, the ARCH-type model is also adopted in order to estimate the conditional expected inflation rate underlying the time-varying conditional variance of the inflation for the Thailand using time series data<sup>2</sup>. The conditional mean equation is formulated as:

$$\Pi = \Pi_t^e + \varepsilon_t \quad (8)$$

$$\Pi^e = E(\Pi_t | \Omega_{t-1}) = Z_t' \omega, \quad (9)$$

where  $\Pi_t$  is the inflation rate and  $\Pi_t^e$  is the expected inflation rate. The  $\varepsilon_t$  is the error terms or unexpected inflation rate component and  $Z_{t-1}$  is the information available to economic agents at time  $t-1$ , which is a subset of  $\Omega_{t-1}$  i.e.  $Z_{t-1} \in \Omega_{t-1}$ . Additionally, the error terms  $\varepsilon_t$  are serially uncorrelated with the zero mean, but they are not necessarily homoskedastic, i.e.  $\varepsilon_t \sim N(0, h_t)$ . Letting  $Z_t$  contain the local macroeconomic variables, namely the narrow money supply (M1), the interest rate (INT),

<sup>1</sup> See Engle, Lilien, and Robins (1987) for more extensive survey on or GARCH(p,q)-M specification.

<sup>2</sup> See Engle (1983), and Coimano and Jansen (1988) for a more extensive survey. However, they applied the ARCH(q) model, which allows only lagged errors from the conditional mean to affect conditional variance.

the GDP, and the lagged inflation rate; an examination will, be carried out by various specification tests for the ARCH-type model of the inflation rate. With equation (8) and (9) the conditional mean equation can be rewritten as:

$$\Pi = \omega + \sum_{t=1}^T \omega_t Z_{t-1} + \varepsilon_t \quad (10)$$

Since the investigation on annual inflation rates are employed by the same methodology as the output, which is fully described above, the empirical regression of conditional variance on inflation rate is not discussed in this section. It is must be noted that the conditional variance  $h_t$  from regressing inflation rate is taken as a proxy for inflation uncertainty. Since the original residuals and conditional variance of inflation is the unexplained portion of the inflation rate estimation associated with economic information, this then represent inflation risks in the marketplace. This could partially be caused by the psychological effects due to monetary policymaker credibility in term of stabilizing the economy.

#### 4. Data Description

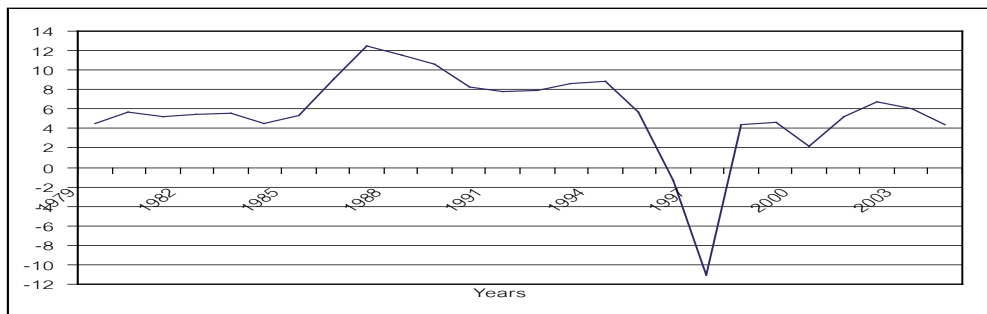
The dataset in this study consists of annual figures for all series data from 1979 to 2005. The annual output of (GDP) and capital stock (K) data are taken from the National Economic and Social Development of Thailand, which are denominated in real term or at a constant price. The agricultural use of land (N) and labor data are obtained from the Office of Agricultural Economics and National Statistics Office of Thailand, respectively. In addition, some particular macroeconomic variables are included to estimate the conditional variance of output or TFP. The numbers of labor in the industrial and agricultural sector are used to calculate the ratio of industrial labor and agricultural labor (RL) as proxy of labor quality which come from the National Statistics Office. Domestic R&D funds data series is gathered from the National Research Council of Thailand. The import of capital goods (IMC) and foreign direct investment (FDI) are gathered from The Bank of Thailand. In order to examine the impact of macroeconomic stability by the cost of inflation uncertainty and the credibility of policymakers in the marketplace, the uncertainty of inflation series data is obtained from the forecast of inflation through the ARCH-type models that is explained in simple terms in the next section. The inflation rate (INF) is measured by the percentage of change in the consumer price index (CPI) which is taken from the National Economic and Social Development of Thailand. Meanwhile the narrow money supply (M1), used to represent the money supply and the Thai Government Bond used as interest rate (INT), are drawn from the Bank of Thailand. The growth rate of the gross domestic product (GGDP) is the first difference forms of the

logarithm of the gross domestic product, and is computed as:

$$GGDP_t = [\ln(GDP_t) - \ln(GDP_{t-1})] \times 100\%$$

where  $\ln(GDP_t)$  is the annual gross domestic product in logarithm form at time  $t$ , which will be again given another short term as  $GDP_t$  in the rest of this study.

**Figure 1** Annual Values of the GGDP (Lower Panel) from 1979 to 2005



The graphical analysis in Figure 1, shows the growth rates of the annual output (GGDP) of the Thai economy from 1979 up to 2005 (26 annual observations). It is apparent that the economic growth of Thailand sheds some light on volatility behavior. In other words, it illustrates the possible phenomenon that large changes tend to be followed by large changes and small changes tend to be followed by small changes in either sign as unexpected shocks on the economy by both internal and external causes, or the so-called business cycle. This typical phenomenon suggests the patterns of time-varying variances which can be successfully captured by the process of conditional heteroskedasticity as discussed earlier in the methodology section.

## 5. Summary Statistics

This study constructs a set of tests based on the annual output or gross domestic product, GDP, of Thailand. Table 1 provides the summary statistics of the sample period from 1979 to 2005, which include the mean, standard deviation, maximum and minimum annual GDP, the measure of skewness and kurtosis, the Jarque-Bara (JB) statistics for normality test, and the Ljung-Box statistics applied on annual GDP. The means (standard deviations) of GDP and its changes, GGDP, are 7.549 (0.492) and 0.057 (0.045) percent, respectively, indicating that changes in GDP is less volatile throughout the sample period. In other words, it illustrates evidence of stationary characteristics. It must be noted that available starting with  $G$  is expressed in logarithmic first difference form of considered variable.

**Table 1** Preliminary Statistic for the Annual GDP

Statistics	Level Form (GDP)	Percentage Change Form (GGDP)
# of obs.	27	26
Max.	8.254	0.125
Min.	6.773	-0.111
Mean	7.594	0.057
S.D.	0.492	0.045
Skew.	-0.348	-2.985
Kur.	1.606	8.881
JB	2.733	54.540 <sup>a</sup>
Q(1)	24.444 <sup>a</sup>	8.798 <sup>a</sup>
Q(2)	44.228 <sup>a</sup>	9.831 <sup>a</sup>
Q(3)	59.686 <sup>a</sup>	10.201 <sup>a</sup>

*Note:* Annual GDP is the logarithmic form of gross domestic production of Thailand and GGDP is the first different form of the GDP,  $GGDP = \log(GDP/GDP_{t-1})$ .

JB is standard Jarque-Bera, Q-statistics is Ljung-Box values, S.D. is the standards deviation, skew and kur. are the skewness and kurtosis values, respectively,

<sup>a</sup> statistically significant at 1% .

The Jarque-Bera test (1987), under the null hypothesis that residuals are normally distributed, which is rejected at the conventional significance level in changes in GDP or growth rate of gross domestic product (GGDP), but it cannot be rejected at it level form, GDP series. In addition, the values of skewness show that the distributions are negatively skewed, relative to the normal distribution. The distributions of GGDP are leptokurtotic, relative to the normal distribution. The reason for this rejection with a negative skewed and leptokurtotic distribution may be the consequence of unknown shocks in the Thai economy, which increases the degree of the market's uncertainty or loss of its confidence and, in turn, sharply slows down activities in the economic system.

Moreover, the Ljung-Box (1978) statistics  $Q(k)$  for  $k = 1, 2$  and 3 lags are used to test for autocorrelation in the annual GDP and GGDP. The null hypothesis of no serial correlation (uncorrelated original stock returns) is rejected at a conventional significant level for both data series. This higher-order serial correlation behavior is the result of economic regulation, policies and the political environment in Thailand, the external economic environment and private sector's decision under economic environment period in the sample.

With the existence of serial autocorrelation in the annual GDP, GGDP must be

fitted with an ARMA model before the test for the null hypothesis of no conditional variance and the nested ARCH (or GARCH) specification. Otherwise, the estimations of univariate time-series in annual gross domestic products may be biased. Although the ARMA specification clearly and completely captures the problem of serial correlation of original residuals of annual gross domestic product, according to values of Ljung-Box,  $Q(k)$  statistics, they are not necessarily a homoskedastic processes. Table 2 shows the computed statistics testing the possible existence of autoregressive conditional heteroskedastic processes. The null hypothesis assumes that the coefficients of the lagged squared residual,  $\varepsilon_{t-1}^2$  from AR(1) estimation are equal to zero. The F-test and Lagrange multiplier test statistic ( $nR^2$ ) with an asymptotic  $\chi^2$  distribution are reported. Regardless of which test is used, the null hypothesis of no conditional heteroskedasticity is statistically significantly rejected at conventional levels for the annual gross domestic product under the consideration period. This suggests that GGDP is not characterized as a white noise process; thus, the ARCH or GARCH model is necessary. This can potentially be a reflection of sharp downturns in the Thai economy. For example, large fluctuations in the rate of growth may occur as a result of remarkable hits, like the mid-1997s Asian financial crisis,

**Table 2** ARCH Tests for the Annual GDP

Variable	Lags	1	2	3
GDP:				
F-Test		6.46 <sup>a</sup>	4.37 <sup>b</sup>	2.69 <sup>c</sup>
nR <sup>2</sup>	AR(1)	5.44 <sup>a</sup>	6.99 <sup>b</sup>	6.81 <sup>c</sup>
Q		0.23	1.02	1.04
Q <sup>2</sup>		6.32 <sup>a</sup>	6.34 <sup>a</sup>	6.64 <sup>b</sup>

*Note:* The null hypothesis assumes that the coefficients regression from the squared residual on its past values are jointly zero:  $\varepsilon_t^2 = \gamma_0 + \sum_{i=1} \gamma_i \varepsilon_{t-i}^2$ . The test statistics are F-statistic (F-stat) and Lagrange Multiplier (nR<sup>2</sup>) test statistic. Q-statistics and Q<sup>2</sup>-statistics are Ljung-Box values.

<sup>a</sup> statistically significant at 1% level, <sup>b</sup> statistically significant at 5% level, and <sup>c</sup> statistically significant at 10% level



Therefore, based on the test results, conditional variance equations are employed here for capturing ARCH error effects on the movement of the Thai economy. In order to make a comparison, the OLS method, which is used to estimate the annual change in gross domestic product (GGDP), is also reported. The following discussion will consist mostly of the results of OLS and standard ARCH models where the likelihood ratio (LR) statistics with an asymptotic  $\chi^2$  distribution are employed to determine the most parsimonious and descriptively accurate model. Further, the test for possible existence of economic variable explanatory power in GGDP and its time-varying variances is performed based upon both t-statistics and likelihood ratio statistics.

Furthermore, the unit root test and stationary test of the annual gross domestic product (GDP) and domestic macroeconomic variables, namely capital stock (K), labor (L), land (N), the ratio of industrial labor and agricultural labor (RL), domestic R&D funds (R&D), import of capital goods (IMC) and foreign direct investment (FDI) in both level and first difference forms for Thai economy. The augmented Dickey-Fuller (ADF) test under the null hypothesis of unit root and the KPSS test under the null hypothesis of a stationary process are applied. However, their statistics are not reported in order to economize space. According to the computed statistics either with an intercept term and the trend, intercept term only, or none of both previous terms, the logarithmic forms (level form) of the annual GDP and of those seven macroeconomic variables, except the inflation uncertainty series as it obtains form estimating on growth function, are likely integrated to be degree one.

To check the robustness of the ADF test results, the KPSS test is employed based upon the LM score from the regression of the variable on a constant and possible on time trend. The statistic is given by a sample autocovariance, as in Newey and West (1987). The unreported KPSS statistics indicates that the null hypothesis of stationarity for those variables in percentage change form cannot be rejected at the conventional significant level. This implies that the levels of the annual data series are featured as non-stationary. In contrast, the percentage change forms of the logarithmic GDP (or GGDP) and eight macroeconomic variables, i.e. GK, GL, GN, GRL, GRD, GIMC, GFDI and GINF, are likely characterized as the integration of degree zero. These findings indicate that all variables employed in the empirical regression should be in the form of logarithmic first differences in order to avoid spurious regressions.

## 6. The Empirical Results

Using the BHHH algorithm, an ARCH or GARCH model relating to the conditional variance to lagged squared residuals is estimated for the growth of gross domestic product of Thailand series. To assess the appropriateness of specification, the likelihood ratio statistics are computed and reported. The likelihood ratio statistics, in

which nested specifications are applied to each pair, involve the additional information variables as an alternative model. For comparison purpose, the ordinary least square (OLS) models with and without particular macroeconomic variables, and ARCH-type models, are employed. If the model is well suited, the errors should be unrelated to the information or the likelihood ratio statistic and should be minimal. A significant test statistic ( $p\text{-value} > 0.05$ ) indicates a preference for the restricted model as opposed to the alternative model. It should be noted that the adoption of a Gaussian distribution is inappropriate. To accommodate the presence of abnormality, the errors those are drawn from, a conditional t-distribution (see Bollerslev, 1986) must be assumed.

The  $T$  value represents time trend in production equation, which is powerless to explain GGDP as indicated by the insignificant values of the  $t$ -statistics. Thus, the coefficient of the trend,  $\phi_T$ , merely measures the average of TFP growth in every estimating model. Again, this insignificant evidence demonstrates that technological change cannot be perceived as a smooth shift of the Thai production function, as mentioned by Felipe (1997). On the other hand, the average of TFP growth may be well defined by alternative technological innovations of which the economy has adopted from internal and external sources. This finding also indicates the evidence of an unstable growth path in the Thai economy, as the impacts of serious unexpected events caused by the Thai political economy and other chaotic and global tragedies, which posed a shock to the Thai market system as a whole. In order to conserve space, the time-series results with trends are not reported here.

Table 3 provides the testing results of the general models for the Thai gross domestic product (GDP) that are used in forecasting its annual growth rate (GGDP) and time-varying variances. The estimations are the regressed results of the OLS and GARCH procedures for Thai GGDP. Equation A reports the original OLS results (AR(1)) while Equation C presents the base GARCH process results as using the maximum likelihood method (AR(1)-GARCH(1,1)). The likelihood ratio statistics yield the tests of the model's restrictions. As figures show in Table 3, generally for all GARCH(1,1) models, the estimated  $t$ -statistics on the coefficients of conditional variance illustrate significantly at conventional levels. Regardless of which model is being employed, not all of the possible exogenous variables i.e. the three main inputs (GK, GL, and GN) and five additional variables (GRL, GRD, GIMC, GFDI, and UINF) appear to be significantly, based on the LR test results. Moreover, the unreported  $t$ -statistics on each coefficient of exogenous variables have insignificant differences from zero or no explanatory power to conditional variance of annual GGDP. Therefore, they can be excluded from the conditional variance of annual GGDP or the GARCH(1,1). The insignificance of coefficients suggests that Thai TFP is best estimated by past lags over considered sample periods.

Nevertheless, the empirical statistics show evidence of the predictive power of some macroeconomic variables on the Thai GGDP. As reported in Equation F (AR(1) model) and D (AR(1)-GARCH(1,1) model) of Table 3, the computed results of t-statistics demonstrate that the growth rate of capital stock ( $GK_t$ ) and its previous growth rate ( $GK_{t-1}$ ), previous growth rate of labor ( $GL_{t-1}$ ), previous growth rate of land used ( $GN_{t-1}$ ), the growth rate of import of capital goods ( $GIMC_t$ ) and growth rate of foreign direct investment ( $GFDI_t$ ), have a statistically significant impact on the conditional mean (Equation F). Meanwhile, only the growth rate of capital stock ( $GK_t$ ), its previous growth rate ( $GK_{t-1}$ ), and previous growth rate of foreign direct investment ( $GFDI_{t-1}$ ), appear to have statistically predictive power of forecasting the conditional mean. However, the factors used to proxy the quality of inputs (i.e. the ratio of industrial labor and agricultural labor, and domestic R&D funds) are statistically insignificant. In addition, both models, incorporating these significant variables, improve the values for the log of the likelihood function, thus regarded as a proper specification for the annual growth rate in the Thai economy. Unfortunately, the AR(1) specification (Equation F) is, somewhat more reasonably proper than the AR(1)-GARCH(1,1) specification (Equation D) for this considered sample period, as a larger value of the log likelihood function. As stated earlier, they demonstrate that those factors' growth generally proves much more important than either the improved quality of factors or total factor productivity growth in explaining output growth, as mentioned by Koop et al. (1999), and Limam and Miller (2003).

Unsurprisingly, capital stock and previous use of land positively contribute to national income while the previous capital stock and labor force negatively affect national income. This empirical evidence illustrates that the accumulation of physical inputs is important for economic growth. However, it does provide interesting patterns by the growth in physical inputs that does not persistently increase national income in all countries. One possible interpretation is that an increase in aggregate input could be far beyond its marginal product that can lead to the fall in output to be lower than its predicted level, thus the TFP. This finding of a negative contribution of both previous capital stock and labor force on the Thai economy can be indicative of policies which distort markets so that available resources have not been allocated to their most efficient use.

The inflation uncertainty (UIF) effect has statistically insignificant explanatory power for forecasting the growth rate of the Thai economy, according to asymptotic t-statistics. This empirical finding reveals the high creditability of the Thai monetary authorities in the economy and the high possibility in keeping their commitment to inflation policy targeting. This belief in government actions in order to keep economic stabilization without tentativeness of any policy shock on the economy would increase market agencies' confidence, therefore economic activities. The proxy of the inflation

uncertainty data series is discussed below with a brief empirical outcome shown in Table 4.

It is interesting that the coefficient on the growth of foreign direct investment has a negative effect on economic growth in Thailand while the growth of import of capital goods generates positive externalities, meaning that not all spillovers are positive. This negative contribution of FDI on Thailand's economic growth may reflect the large technology gap between domestic and foreign firms and the insufficient technological absorptive capacity in domestic firms (see Borensztein et al., 1998, and Damijan, et al., 2003, among others). In addition, the insignificant explanatory power of the ratio of industrial labor, agricultural labor, and domestic R&D funds on the growth of gross domestic product in Thailand clearly support the evidence of negative externality. These two variables are reasonably used as the proxy of input quality by which both terms capture the innovative and absorptive capability of domestic firms. Both factors reflect innovative effect and learning, the absorption effect of R&D, and educational and training activities. In other words, they demonstrate the ability of domestic firms in identifying, assimilating and exploiting knowledge spillovers. The stock of human capital and several types of investment in human capital are the form of capital that is most likely responsible for unexplained increases in national income as one can be answered by absorptive capability of technology which can be regarded as a possible way to close the technology gap between developed and undeveloped countries (see Andreosso-O'Callaghan, 2002).

However, the imports of capital goods statically show important vehicles of international knowledge spillovers and confirms the Coe and Helpman (1995) empirical findings. According to this positive externality, the open economy, is a key of important income contribution for national income as the gateway of suitable level technology transferred from developed countries. Coe and Helpman generally provide evidence on such beneficial effects of international R&D through international trade on domestic productivity. Turning to the effect of the direction of technological diffusion on growth, according to empirical results, both channels promote an opposite effect that could possibly be a reflection of differences of technological nature between FDI and domestic investment. The positive effect of the import of capital goods may provide evidence of domestic technological accordance due to host investors' decision making on technological choices. It should also be noted that the significance of estimated parameter AR(1) reflects the long memory effect of which the result of economic and political environment in Thai economy.

**Table 3** The OLS Estimation of the Equation for the Conditional Expectation of Annual GDP

**Base AR(1)** :  $GGDP_t = \varphi + \alpha_1 GGDP_{t-1} + \varepsilon_t$  A

**Base AR(1)-GARCH(1,1)** :  $GGDP_t = \varphi + \alpha_1 GGDP_{t-1} + \varepsilon_t$  C.1

$h_t = a_0 + a_1 \varepsilon_{t-1}^2 + b_1 h_{t-1}$  C.2

Parameters	Equation A	Equation B	Equation C	Equation D
Conditional Mean Equation:				
$\phi$	0.057 <sup>a</sup> (3.31)	0.039 <sup>a</sup> (6.88)	0.106 (0.57)	0.036 <sup>a</sup> (6.55)
$\alpha_1$	0.570 <sup>a</sup> (3.15)	-0.507 <sup>a</sup> (-2.52)	0.958 <sup>a</sup> (7.181)	-0.305 (-1.07)
GK	-	3.155 <sup>a</sup> (16.39)	-	3.081 <sup>a</sup> (12.29)
GK{1}	-	-2.753 <sup>a</sup> (-13.89)	-	-2.657 <sup>a</sup> (-10.84)
GL	-	-	-	-
GL{1}	-	-0.318 <sup>a</sup> (-2.44)	-	-0.209 (-0.88)
GN	-	-	-	-
GN{1}	-	0.675 <sup>c</sup> (1.80)	-	0.332 <sup>a</sup> (3.38)
GRL	-	-	-	-
GRL{1}	-	-	-	-
GRD	-	-	-	-
GRD{1}	-	-	-	-
GIMC	-	-	-	-
GIMC{1}	-	-	-	-
GFDI	-	-	-	-
GFPI{1}	-	-	-	-
UINF	-	-	-	-
UINF{1}	-	-	-	-
Conditional Variance Equation:				
$a_0$	-	-	0.000 (1.33)	0.000 (0.25)
$a_1$	-	-	0.666 (1.89)	-0.322 <sup>a</sup> (-3.54)
$b_1$	-	-	0.004 <sup>b</sup> (0.01)	1.250 <sup>a</sup> (2.81)
# of obs.	25	24	25	24
Log(L)	46.653	68.128	55.921	71.828
Skew.	-1.433	-0.219	-0.037	-0.486
Kur.	7.172	2.523	2.844	2.220

**Table 3** The OLS Estimation of the Equation for the Conditional Expectation of Annual GDP (continued)

Parameters	Equation E	Equation F	Equation G	Equation D
Conditional Mean Equation:				
$\phi$	0.030 <sup>b</sup> (2.33)	0.031 <sup>a</sup> (5.25)	0.028 (1.53)	0.037 <sup>a</sup> (9.47)
$\alpha_1$	-0.139 (-0.50)	-0.480 <sup>a</sup> (-2.07)	0.145 (0.04)	-0.360 <sup>b</sup> (-1.74)
GK	2.400 <sup>a</sup> (3.56)	2.644 <sup>a</sup> (9.67)	2.392 <sup>a</sup> (3.10)	3.034 <sup>a</sup> (21.13)
GK{1}	-1.980 <sup>a</sup> (-3.37)	-2.247 <sup>a</sup> (-8.21)	-1.960 <sup>a</sup> (-2.59)	-2.621 <sup>a</sup> (-20.13)
GL	-	-	-	-
GL{1}	-1.046 (-1.44)	-0.301 <sup>a</sup> (-2.52)	-1.159 (-1.68)	-
GN	-	-	-	-
GN{1}	1.440 (1.66)	0.790 <sup>a</sup> (2.34)	1.574 (1.12)	-
GRL	0.030 (2.28)	-	0.080 (1.04)	-
GRL{1}	-0.053 (-0.43)	-	-0.071 (-0.53)	-
GRD	-0.006 (-0.22)	-	-0.013 (-0.31)	-
GRD{1}	0.014 (0.60)	-	0.018 (0.46)	-
GIMC	0.119 (1.58)	0.069 <sup>b</sup> (2.40)	0.138 <sup>a</sup> (2.36)	-
GIMC{1}	0.018 (0.29)	-	0.006 (0.10)	-
GFDI	-0.023 (-0.90)	-0.019 <sup>c</sup> (-2.03)	-0.023 (-1.05)	-
GFPI{1}	0.012 (0.44)	-	0.021 (0.71)	-0.015 <sup>a</sup> (-2.47)
UINF	-0.421 (-0.47)	-	-0.387 (-0.47)	-
UINF{1}	-0.342 (-0.29)	-	-0.584 (-0.51)	-
Conditional Variance Equation:				
$a_0$	-	-	0.000 (0.43)	0.000 <sup>c</sup> (1.68)
$a_1$	-	-	-0.304 (-0.44)	0.231 <sup>b</sup> (1.97)
$b_1$	-	-	1.136 <sup>a</sup> (4.68)	-1.051 <sup>a</sup> (-5.34)
# of obs.	22	24	22	24
Log(L)	68.475	72.330	68.844	69.278
Skew.	0.102	0.083	0.449	-0.466
Kur.	2.510	2.392	1.950	2.641
JB	0.258	0.396	1.749	1.039
nR <sup>2</sup> (1)	0.375	2.024	0.489	0.004
nR <sup>2</sup> (2)	0.739	3.014	0.420	3.477
LR(2)		8.403 <sup>a</sup>		
LR(6)		56.032 <sup>a</sup>		
LR(10)	12.865		12.694	

Note: GDP, K, L, N, RL, RD, IMC, and FDI represent the logarithmic form of gross domestic product of Thailand, capital, labor, land, ratio of industrial labor and agricultural labor, domestic R&D funds, import of capital goods, and foreign direct investment, respectively.

The percentage change form is the first difference form of the level form,  $GK = \log(K_t/K_{t-1})$ ,  $GL = \log(L_t/L_{t-1})$ ,  $GN = \log(N_t/N_{t-1})$ ,  $GRL = \log(RL_t/RL_{t-1})$ ,  $GRD = \log(RD_t/RD_{t-1})$ ,  $GIMC = \log(IMC_t/IMC_{t-1})$ ,  $GFDI = \log(FDI_t/FDI_{t-1})$ , and UINF is the inflation uncertainty.  $\alpha$ 's are the coefficients of logged GGDP.  $a$ 's and  $b$ 's represent the coefficients of lagged conditional variance and errors from conditional variance.  $nR^2$  is Lagrange multiplier test statistics. LR is likelihood ratio test between models with and without incorporating other economic variables,  $\text{Log}(L) = \log$  function likelihood, and the numbers in the bracket are the t-statistics.

<sup>a</sup> statistically significant at 1% level, <sup>b</sup> statistically significant at 5% level, and <sup>c</sup> statistically significant at 10% level.

Unfortunately, the unreported computed results show that those additional determinants of production function have no explanatory power in explaining the conditional variance or TFP used in this study. Therefore, they all can be excluded from the conditional variance of annual GDP. Thus, the TFP could not be applied by using a one-step decomposition approach as this research wishes to introduce. One econometric reason of this insignificance is possibly caused by a small sample size with a yearly frequency which could cause the doubtful pattern of substantial time-varying variance or heteroscedastic process in unexplained portions of production function. Hence, the traditional econometric technique is proper to estimate the growth rate of Thai GDP. If those additional variables could statistically significantly explain growth rate, this would implicitly explain this unexplained portion of growth.

Despite the log likelihood function, it is worth mentioning that the sum of the GARCH coefficients is very close to unity. It indicates that the GARCH is integrated in variance. The aggregate value of coefficients in GARCH(1,1) implies that the shocks to variance, those that have substantial persistence and movement of the Thai economy, cannot be explained by the rational expectations of market agencies or economic activities. Consequently, current event(s), influence economic agencies' decision or confidence, for example, economic policies, new innovations under globalization, world issues and so forth, which could affect total factor productivity, and economic productivity over long horizons due to imperfections in the Thai economy.

As discussed previously, in order to construct a time series for expected inflation and to get estimation for the variance of unexpected inflation as a proxy of inflation uncertainty, equations such as those presented in the method of analysis section, can be estimated. The first step consists of regressing the observed inflation rates on the set of instruments up to 1 lag. To economize space, the empirical results from both OLS and ARCH models are presented in Table 4 while several diagnostic tests for model adequacy are unreported.

Based on the unreported results of various tests, the inflation series in the Thai economy exhibit serial autocorrelation with a white noise process. Such a characteristic would mean that past available information could have been used to improve the forecasting of inflation series. Fortunately, the lagged inflation and the three macroeconomic variables might strongly explain the autocorrelation process as shown by insignificant unreported Q-statistics. Despite the Ljung-Box statistics, the computed t-statistics on the estimated estimators illustrate that the models, incorporating some particular macroeconomic variables (Equation D), are significantly superior to the other approaches, the simplest OLS model (Equation A) and



GARCH(1,1) model (Equation C), as shown in Table 4. This finding also allows treating the level of inflation uncertainty as a white noise process in the considered sample. A suggestion is that OLS frameworks are appropriate for estimating the inflation series on the Thai economy.

Consequently, the level of inflation uncertainty can be obtained from the OLS estimations, AR(1,4) including three macroeconomic variables, namely GM1, GM1{1}, GINT{1}, GGDP, and GGDP{1}. After testing the unit root tests of this cost on the growth of the Thai economy to avoid spurious regression results, the levels of inflation uncertainty is featured as stationary, the inflation uncertainty as a proxy of economic stabilization is then ready to be estimated by incorporating inflation uncertainty data series in both the OLS and the conditional variance models in explaining growth of Thailand as fully described above.

**Table 4** The OLS Estimation of the Equation for the Conditional Expectation of Inflation on Thailand

<b>Base AR(1,4)</b>	:	$INF_t = \varphi + \omega_1 INF_{t-1} + \omega_4 INF_{t-4} + \varepsilon_t$	<b>A</b>
<b>Base AR(1,4)-GARCH(1,1)</b>	:	$INF_t = \varphi + \omega_1 INF_{t-1} + \omega_4 INF_{t-4} + \varepsilon_t$	<b>C.1</b>
		$h_t = a_0 + a_1 \varepsilon_{t-1}^2 + b_1 h_{t-1}$	<b>C.2</b>

Parameters	Equation A	Equation B	Equation C	Equation D
Conditional Mean Equation:				
$\phi$	0.039 <sup>a</sup> (7.42)	0.025 <sup>a</sup> (2.44)	0.041 (6.01)	0.016 <sup>a</sup> (2.30)
$\omega_1$	0.457 <sup>a</sup> (2.47)	0.586 <sup>a</sup> (2.56)	0.548 (2.27)	0.330 <sup>a</sup> (3.53)
$\omega_4$	-0.191 <sup>b</sup> (-1.96)	-0.119 (-0.95)	-0.165 (-1.33)	-
GM1	-	0.084 <sup>c</sup> (1.79)	-	0.114 <sup>a</sup> (3.09)
GM1{1}	-	0.118 <sup>a</sup> (2.61)	-	0.153 <sup>a</sup> (4.18)
GINT	-	0.002 (0.58)	-	-
GINT{1}	-	0.006 <sup>a</sup> (3.13)	-	0.007 <sup>a</sup> (4.26)
GGDP	-	-0.371 <sup>a</sup> (-4.55)	-	-0.447 <sup>a</sup> (-5.91)
GGDP{1}	-	0.253 <sup>a</sup> (3.05)	-	0.317 <sup>a</sup> (5.23)
Conditional Variance Equation:				
$a_0$	-	-	0.000 (0.65)	-
$a_1$	-	-	0.449 (0.80)	-
$b_1$	-	-	-0.042 (-0.04)	-
# of obs.	21	21	22	24
Log(L)	59.704	74.207	62.702	83.334
Skew.	-1.015	0.229	0.205	-0.113
Kur.	5.946	1.781	3.871	2.295
JB	11.734 <sup>a</sup>	1.484	0.849	0.548
nR <sup>2</sup> (1)	1.325	0.046	2.153	0.019
nR <sup>2</sup> (2)	2.039	1.293	3.808	1.982
LR(5)				40.002 <sup>a</sup>
LR(6)		37.314 <sup>a</sup>		

Note: CPI, M1 and GDP represent the logarithmic form of consumer price index, narrow money supply, and gross domestic product of Thailand, respectively. INT is interest rates.

The percentage change form is the first difference form of the level form,  $INF = \log(CPI_t/CPI_{t-1})$ ,  $GM1 = \log(M1_t/M1_{t-1})$ ,  $GGDP = \log(GDP_t/GDP_{t-1})$ , and  $GINT = (INT_t - INT_{t-1})$  measure inflation rate, growth in M1, growth in GDP, and the first difference of INT, respectively.

$\omega$ 's are the coefficients of logged inflation.  $a$ 's and  $b$ 's represent the coefficients of lagged conditional variance and errors from conditional variance.  $nR^2$  is Lagrange multiplier test statistics.

LR is likelihood ratio test between models with and without incorporating the first difference form of INT, and of logarithmic M1 and GDP.

Log(L) = log function likelihood, and the numbers in the bracket are the t-statistics.

<sup>a</sup> statistically significant at 1% level, <sup>b</sup> statistically significant at 5% level, and <sup>c</sup> statistically significant at 10% level.

## **7. Conclusions**

In this study, the literatures on productivity growth are clearly constructed in order to detect an empirical explanation of phenomenon in the Thai economy. The notion of productivity used is the Solow residual, which was estimated through the econometric estimation of the Cobb-Douglas production function in the Thai economy during 1979-2005. A Cobb-Douglas specification includes three main inputs (the capital stock, labor force and land used), as well as the proxy of input quality (domestic R&D funds, ratio of industrial labor and agricultural labor), the channels for the transfer of technology (the imports of capital goods, and foreign direct investment), and the proxy of economic instability (the inflation uncertainty), in order to explain economic growth. In order to introduce the advanced methodology to model the volatility of economic growth rate, a GARCH process with BEKK parameterization is applied to reflect the well-known autoregressive behavior in volatility series or total factor productivity in this study. However, the ARMA process is generally used in explaining the economic growth rate. Thus, the comparison between the GARCH and ARMA process is mandatory.

According to the empirical findings, the decomposition of output growth demonstrates that the factors' accumulation generally indicates more significant importance than the improved quality of factors, economic instability or total factor productivity growth in explaining output growth in Thailand. Unfortunately, the result of the log likelihood function tends to reject the AR(1)-GARCH(1,1) specification in favor of the AR(1) process. However, the estimated t-statistics on the coefficients of conditional variance are largely significant at the conventional level. Therefore, it should be mentioned that the summation of the GARCH coefficients is very close to unity. This implies that any shock to variance has substantial persistence, and movement of the Thai economy cannot be explained by the rational expectations of market agencies or economic activities.

More interestingly, the empirical results illustrate the strong evidence of negative externality from foreign countries, which can contribute to overall domestic productivity growth only when there is a large technology gap between domestic and foreign firms. This could reflect insufficient technological absorptive capabilities of domestic entities, such as entrepreneurs, labor forces, the academy, and so on. As demonstrated by foreign direct investment (FDI), empirical finding possesses a negative and significant effect in all models while the proxy of input quality is powerless in explaining growth of output. It is obvious that technological change is independent from human inputs and human creates and utilizes technologies, therefore

human capital has to be promoted to bolster those high technological level form developed countries. Consequently, the governmental policies for promoting FDI may not be sufficient for the Thai economy, especially in the aspect of welfare ground improvement unless the government concurrently enhances and encourages investment in R&D and upgraded national technological absorptive capability. However, the imports of capital goods are the indirect technological diffusion leading to positive technological knowledge spillovers from developed nations. Notably, the implementation of technological diffusion on economic growth and governmental economic distortions on FDI as mention in Borensztein et al. (1998) must especially be noted and utilized as a tool for further investigation related to this research.

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